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INFLUENCE OF TWO POWER SYSTEMS WITH DIFFERENT RATED FREQUENCIES

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ABSTRACT

The paper is attended to the problem of the detection of the influence having one power system to another one if these power systems are characterized by different rated frequencies. The first power system ($U_{N1} = 110$ kV, $f_1 = 16{,}7$ Hz) contains many transmission lines located close (joint-use corridors, crossings and common supports) to the transmission lines of the second power system ($U_{N2} = 380$ kV, $f_2 = 50$ Hz). It originates the 50 Hz components and their harmonics in the 16,7 Hz electrical system.

Index Terms - transmission lines, spectrum analysis, measurement data, necessary resolution, factual resolution, volt–ampere characteristics method, derivative, differentiation rule, signal in digital form, volt-ampere characteristic square

1. INTRODUCTION

This problem has already been examined in [1], where attention was paid to the fact, that a large fetch time of $t_s \cong 10$ sec is required for the detection of the target fact with a resolution of 0,1 Hz by the traditional methods of spectrum analysis (SA) [2]. It requires respectively a large array of measurement data.

2. MEASUREMENT DATA

The field of data $u(t_i)$ which was at the authors' disposal is shown in Figure 1.

The field of data parameters is: sampling increment $\Delta t = 7{,}8115 \cdot 10^{-5}$ sec; field length $N = 8001$; signal fetch time $t_S = N \cdot \Delta t = 0{,}625$ sec.

The necessary resolution is

$$\delta F_N \cong \frac{1}{t_s} = \frac{1}{10} = 0{,}1 \text{ Hz.} \qquad (1)$$

The factual resolution is

$$\delta F_F \cong \frac{1}{t_S} = 1{,}6 \text{ Hz.} \qquad (2)$$

It can be seen that $\delta F_N < \delta F_F$. Thus a solution of the considered problem is obstructed by using the traditional methods of SA.

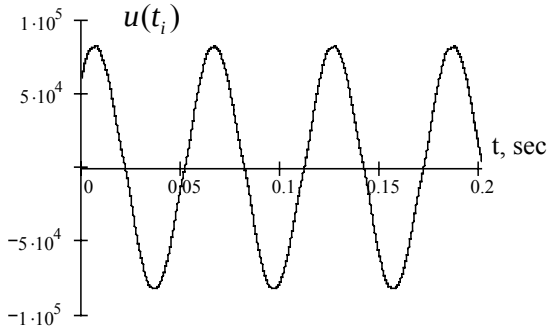

Figure 1. Voltage oscillogram under investigation, electric signal $f_N = 16{,}7$ Hz.

The second difficulty of the assessment the problem mentioned above is illustrated by table 1, where the frequencies and the harmonics of the systems (two power systems (PS)) as well as the required resolutions are shown.

Table 1.

Caption	Harmonic frequencies, Hz		
PS №1	$f_1 = 16{,}7$	$f_3 = 50{,}1$	$f_5 = 83{,}5$
PS №2		$f_1 = 50{,}0$	-
δF_N	-	0,1	-

Continuation of table 1

Caption	Harmonic frequencies, Hz		
PS №1	$f_7 = 116{,}9$	$f_9 = 150{,}3$	$f_{15} = 250{,}5$
PS №2	-	$f_3 = 150$	$f_5 = 250$
δF_N	-	0,3	0,5

3. USED METHODS

The SA by the volt–ampere characteristics method (MVAC) is described in [3,4,5]. On this base an improved method IMVAC was developed and applied. With the help of this method, the analysis for an analyzable signal $u(t_i)$ and its first derivative $\dot{u}(t_i)$ (derivative is used only for the detection of frequencies) (see figure 2), received by the numerical differentiation rule [6], was carried out.
The basic differentiation rule is:

$$\dot{a}(t_i) = \frac{1}{12 \cdot \Delta t}[(a(t_{i-2}) - a(t_{i+2})) - 8(a(t_{i-1}) - a(t_{i+1}))]\Big|_{j=1}^{N} \quad (3)$$

The resulting oscillogram of the first derivative $\dot{u}(t_i)$ of the analyzed signal is presented in Figure 2.

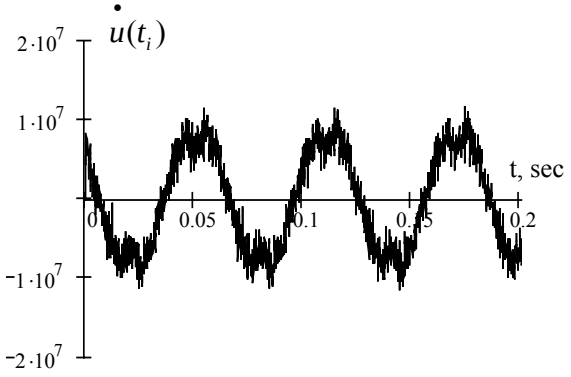

Figure 2. Oscillogram of the first derivative of the analyzable signal $\dot{u}(t_i)$.

The basic procedures of the IMVAC is:

$$Q_{VAC} = \frac{1}{4\pi}\sum_{i=1}^{N}[a(t_i) - a(t_{i+1})] \cdot [b_0(t_i) + b_0(t_{i+1})]; \quad (4)$$

$$Am_k = \frac{2 \cdot Q_{VAC}(\omega_{0k})}{w_{\max}}, \quad (5)$$

where $a(t_i)$ - signal under consideration in digital form, $b_0(t_i) = \sin(\omega_{0k} t_i + \frac{(\varphi_{0k} - 90) \cdot \pi}{180})$ - reference signal in digital form; Q_{VAC} - volt-ampere characteristic square; N - field length of the signal under consideration; $w_{\max} = trunc(N \cdot f_k \cdot \Delta t)$ - total oscillation amount with frequency under consideration during the fetch time t_s, Am - amplitude under reference signal frequency $f_{0k} = \frac{\omega_{0k}}{2\pi}$ Hz and under $\max[Q_{VACk}(\varphi_{0k})]$.

4. INVESTIGATION RESULTS

The IMVAC calculation results for the signal $u(t_i)$ to be analyzed and its first derivative $\dot{u}(t_i)$ are given in table 2, 3.

Table 2:

Analysis results $u(t_i)$		
f, Hz	Am, V	φ, degree
16,61	78008,72	59
50,17	3035,38	-29
83,52	1085,836	78
116,68	569,2542	-134
150,24	429,73	-69
183,57	324,694	-84
216,99	211,271	-81
250,78	43	-11

Table 3:

Analysis results $\dot{u}(t_i)$		
f, Hz	Am, V	φ, degree
16,56	77870,511	65
50	2966,652	-11
50,07	3005,94	-19
83,46	1084,403	86
116,89	558,486	-156
150,04	415,344	-50
150,22	429,636	-67
183,63	323,947	-90
217,05	210,748	-88
250,05	30,302	94
250,38	36,634	40

For illustrating the determination of the frequencies examples of the amplitude-frequency characteristics (AFC) in % from the maximum importance for the analyzed signal $u(t_i)$ was developed (see figure 3)

and for the first derivative of the analyzed signal $\dot{u}(t_i)$ (see figure 4).

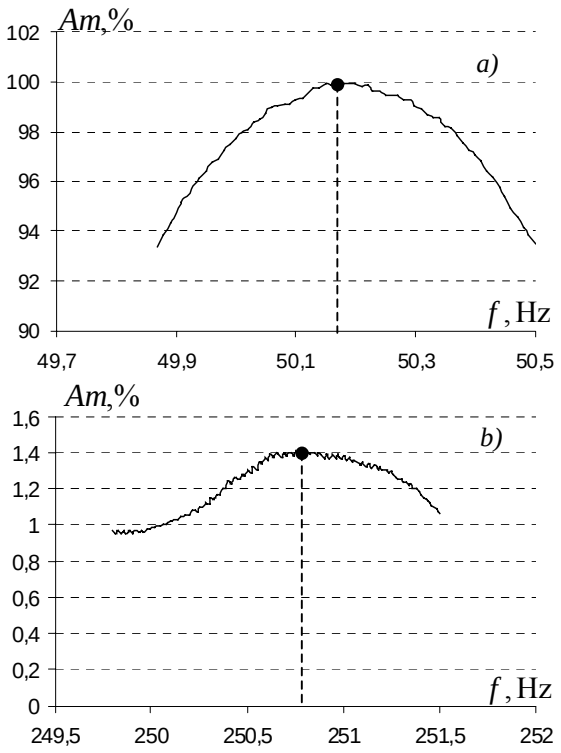

Figure 3. AFC of the analyzed signal $u(t_i)$ by IMVAC.

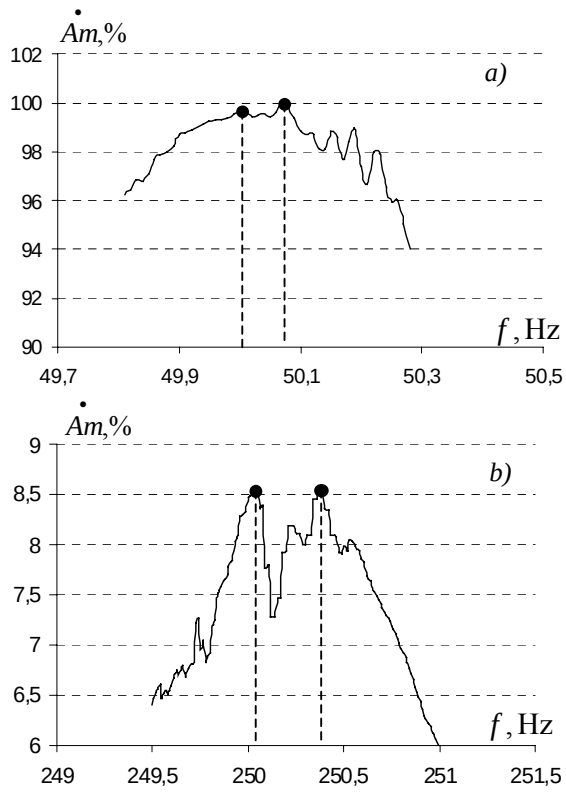

Figure 4. AFC of the first derivative of the analyzed signal $\dot{u}(t_i)$ by IMVAC.

5. SUMMARY

The data analysis in tables 2 and 3 allows to confirm, that there are frequency constituents, pointed at the fact of interference of two electric power systems: 50; 50,07; 150,04; 150,22; 250,05 and 250,38 Hz.
The facts pointed out above allows to recommend this method (IMVAC) for the application of the differentiation of signal picked-up for the detection of frequency components to solve problems which are similar to that one examined.

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